SPRINGFIELD ARMORY

SPRINGFIELD, MASSACHUSETTS

RESEARCH AND ENGINEERING

Report: SA-TR18-1084

Date: 9 April 1964

CMS Code: 5016.11.84400.02

Report Title: Factors Influencing Friction of Phosphate Coatings

Author *Michael A. George*
MICHAEL A. GEORGE
Chem Eng

Approved *Stanley C. Skeiber*
STANLEY C. SKEIBER
Lt Col, Ord Corps
Chief, Res and Eng Div

SWESP Form 722
Rev. 10 Jun 63

Report: SA-TR18-1084

Date: 9 April 1964

CMS Code: 5016.11.84400.02

Report Title: Factors Influencing Friction of Phosphate Coatings

Author Michael A. George
MICHAEL A. GEORGE
Chem Eng

Approved Stanley C. Skeiber
STANLEY C. SKEIBER
Lt Col, Ord Corps
Chief, Res and Eng Div

Project Title: In-House Laboratory, etc.

PRON: M1-3-50016-02-M1-M6

Preparing Agency: Springfield Armory, Springfield, Mass.

This TECHNICAL REPORT, to the extent known, does not contain any patentable material, copyrighted and/or copyrightable material, trade secrets, or trade names.

NONLIMITATION OF REPRODUCTION AND DISTRIBUTION. Distribution of this report is nonlimited. Initial distribution has been made in accordance with the attached distribution list. Reproduction and/or distribution by any installation or agency is authorized.

DISPOSITION: Destroy. No not return.

BLANK PAGE

REPORT
SA-TR18-1084

ABSTRACT

A friction and wear machine has been developed at Springfield Armory to simulate the frictional characteristics of reciprocating weapon components. The machine was used to evaluate the various factors influencing the friction of phosphate coatings. Coefficients of friction for the coatings were determined under static and dynamic conditions. The following factors influencing the coefficient of friction are considered: type of coating, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not differ to any practical extent from the coefficients for zinc phosphate coatings. Lubrication is a significant factor on the coefficients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing, surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed.

REPORT
SA-TR18-1084

CONTENTS

REPORT
SA-TR18-1084

SUBJECT

Factors Influencing Friction of Phosphate Coatings

OBJECTIVES

To investigate the various factors influencing the frictional behavior of phosphate coatings with the use of Springfield Armory reciprocating testing machine.

SUMMARY OF CONCLUSIONS

1. The testing apparatus will give adequate reproducibility of results.

2. A slight statistically significant difference was found between the mean static coefficient of friction for zinc phosphate (.876) and manganese phosphate (.913) coatings when unlubricated. This difference of 3 per cent is believed to have no practical significance.

3. Dry phosphate coatings have poor frictional characteristics and are not natural lubricants. Lubricated phosphate coatings with MIL-L-644 oil reduce the static coefficient of friction to approximately one sixth the value of the dry coating. The mean values are .145 for zinc phosphate and .147 for manganese phosphate.

4. The static coefficient of friction is independent of load.

5. A comparison of the smooth dry phosphate coatings on a vapor-blasted surface with the dry phosphate coatings on a grit-blasted surface shows that the static coefficient of friction for the smoother surface (.858) is slightly less than for the grit-blast surface (.897). However, when the coating with vapor-blasting is oiled, its coefficient (.209) is greater than that for the oiled coating with grit blasting (.147).

6. Dry phosphate coatings with very coarse crystalline structures have a lower static coefficient of friction (.766) than standard coatings with a proper surface preparation (.913). The standard coatings have a lower coefficient when lubricated. The standard coatings have a mean coefficient of .147 as compared with a mean coefficient of .178 for the coarse crystalline coatings.

SUMMARY OF CONCLUSIONS - Continued

7. The maximum dynamic coefficient of friction for lubricated phosphate coatings during reciprocating motion approximates the static coefficient of friction. The mean static coefficients for lubricated zinc and manganese phosphate are .145 and .147, respectively; whereas, the mean maximum dynamic coefficients for zinc and manganese phosphate are .150 and .153 respectively.

8. Velocity has an effect on the dynamic coefficient of friction. The mean coefficients of friction at maximum velocity during the stroke were less than values at the ends of the stroke. The mean dynamic coefficients at maximum velocity were .113 for zinc phosphate and .116 for manganese phosphate.

RECOMMENDATIONS

1. All phosphate coatings should be lubricated to reduce friction.

2. As far as frictional properties are concerned, zinc and manganese phosphate coatings should be used interchangeably.

3. The effect of other lubricants on the frictional values of phosphate coatings should be studied.

4. Static coefficients of friction for lubricated phosphate coatings should be used to determine the maximum dynamic coefficient of friction present in reciprocating motion.

5. A quantitative study should be made of the relationship of velocity to the dynamic coefficient of friction.

1. INTRODUCTION

It is easy to misinterpret some coefficients of friction. Handbooks list these coefficients for some combinations of materials, and a literature search will reveal more. Conditions under which the values were obtained are usually not given and when they are, they seldom apply to a specific test condition. The quoted value may be in error from 25 per cent to as much as 200 per cent.[1]

At present, development and design engineers have only vague and meager information concerning frictional and wear properties of various coatings for use in designing weapons. The information which is available usually has been obtained from small pieces sliding on large circular discs under steady state conditions and is not necessarily applicable to reciprocating motion.

A friction-and-wear machine has been developed at Springfield Armory to simulate the actual wear of small caliber weapon components in motion. The machine reciprocates one block between two stationary blocks. This machine is designed to operate under loads from 32.1 pounds to 417.1 pounds, speeds from 600 r.p.m to 2000 r.p.m., and strokes up to approximately 2.5 inches.

Friction-and-wear considerations are very important in the functioning of weapons. For instance, in the M14 rifle, the movement of the bolt sliding on the receiver rails and the operating rod assembly sliding on the outside tracks of the receiver are examples of phosphate coatings sliding upon phosphate coatings. The M85 machine gun has chromium-plated wear components such as the slide breechblock and the barrel extension. Aluminum components are anodized and hard-anodized to increase the resistance to wear.

It has been proposed that measurements of the coatings used in weapons be evaluated with the use of Springfield Armory testing machine. A guide book for design engineers would be prepared on the information compiled. Phosphate, oxide, metallic, and organic coatings would be evaluated and the frictional values tabulated.

This report on the friction-and-wear project is concerned with the feasibility of using the friction machine to reproduce results, and the static and dynamic coefficients of friction for phosphate coatings. The scope of the investigation will include a comparison of zinc versus manganese phosphate, dry versus lubricated coatings, static coefficients versus dynamic coefficients, and the effect of load, surface roughness, and crystallinity on the coefficient of friction. The sample blocks used are similar to many standard weapon parts insofar as material, hardness, and surface finishing are concerned.

2. MATERIALS AND EQUIPMENT

a. Springfield Armory Friction-and-Wear Testing Machine (Figs. 4 and 5), Dwg. No. SA-F-39615.

b. Friction Blocks (Fig. 6), Material 4340 steel of Rockwell C hardness 45 to 50. Each set consists of two 3" by 2" by 3/8" blocks and one 1-1/4" by 1-1/4" by 1/2" block. Dwg. Nos. SA-F-39616 and SA-F-39617.

c. Strain gages - four 120 ohm gages connected as a Wheatstone bridge circuit.

d. Strain gage amplifier - Sanborn Model No. 64-500A with control panel Model No. 60-1600.

e. Recorder - Sanborn Twin - Viso Recorder Model No. 60-1300

f. Recording Paper - Sanborn 2-channel Permapaper (Fig. 2).

3. PROCEDURE

a. Calibration of Friction Machine and Instrumentation

(1) Normal force

The normal force equals the load applied to the friction blocks. The load may be increased by the addition of weights to a tray attached to a lever arm. When no weights are added, the load consists of the weight of the upper friction block attached to its holder, and the reaction of the weight of the lever arm and weight tray applied at the point where friction occurs (See Fig. 1). This basic load was measured with a force indicator and found to be 32.1 pounds.

The lever arm acts as a second-class lever. The total length of the arm is 16.5 inches and the distance between the point at which the force is applied to the friction block and the weight tray is 15 inches. This results in a mechanical advantage for the arm of 11-1. Readings on the force indicator increased 11 pounds for each 1 pound weight on the tray and thus verified this reasoning.

PROCEDURE - Continued

(2) Friction force

The friction force is calculated from strain measurements obtained by the use of strain gages attached to the reciprocating rod which drives the moving friction block. In the calibrating of the equipment, this rod was placed under tensile and compressive loads with a tensile machine. Equal deflections in opposite directions on the recorder for similar loads were obtained under tensile and compressive conditions. A linear relationship between the load and the deflection on the recorder was obtained: a 1-millimeter deflection corresponds to a 5-pound load.

(3) Force due to Acceleration

In reciprocating motion, forces due to acceleration are present because velocity is not constant. The rotary motion of the motor is changed to rectilinear motion by a crank-and-connecting-rod mechanism. A plot of velocity versus time for this mechanism gives a curve which approximates a sine wave. The maximum velocity would be approximately at the mid point of the stroke and zero velocity at the extremes of the stroke. The acceleration is 90 degrees out of phase with the velocity, thus zero acceleration exists at maximum velocity and maximum acceleration at the extremes.

The force due to acceleration was determined easily when the machine was operated with the middle block alone. Thus, the friction forces were eliminated. The acceleration forces were dependent upon the length of stroke and the number of revolutions per minute of the motor. A short stroke and a low motor speed were used so that the effect of acceleration could be minimized. The values selected for all dynamic tests were a 1-inch stroke and 600 r.p.m. Under these conditions, the maximum recorder deflection for one cycle of movement was estimated to be only 1 millimeter.

PROCEDURE - Continued

b. Preparation of Test Specimens

(1) Machining

The 4340 steel blocks used in the testing were heat treated and quenched to a final hardness of Rockwell C 45 - 50. Final surface grinding produced surfaces that were parallel within .0002 inch and gave surface roughness values of 4 to 6 microinches (r.m.s.) as measured on a profilometer.

(2) Surface Preparation

The specimens after degreasing were abrasive blasted with steel grit (number 120). An exception to this procedure occurred in the surface roughness study when two alternate blasting techniques were used. A vapor-blast with the use of abrasive number 200 and a table grit-blast with a mixture of steel grit (numbers 50 and 80). No blasting was necessary for the coarse crystalline coatings since a 50 per cent hydrochloric acid dip was used.

(3) Phosphating

The phosphating of the specimens was accomplished in a standard laboratory bath. The manganese phosphate solution had the following controls: total acid 55 - 65 points, free acid 10 - 11 points, and iron .1 to .3 per cent. The zinc phosphate solution had the following controls: total acid 28 - 30 points, free acid 4 - 6 points, and iron .1 to .3 per cent. The blocks were phosphated for 30 minutes in a bath at 205° F. A hot water rinse and a chromic acid rinse followed. The lubricated blocks were dipped in oil conforming to specification MIL-L-644.

c. Friction Testing

Proper balancing of the instrumentation was necessary before each series of tests. When the blocks were placed in the friction machine, some adjustments were necessary to obtain even wear. This was accomplished by the adjustment of 8 rollers which control the placement of the holder of the upper friction block (Fig. 1).

PROCEDURE - Continued

After an adequate wear pattern had been achieved, the movable block was pushed back and forth several times to break in the coating. Initial friction values are not considered important since phosphate coatings usually offer rapid break in qualities.

Static friction conditions were simulated by pushing the movable block by hand back and forth at a slow rate. Weights were added to the tray in 1-pound increments. The dynamic tests were operated at 600 r.p.m. and a 1-inch stroke. The weights were added to the tray in 5-pound increments. The total maximum recorder deflection for both the static and dynamic testing and the corresponding loads were tabulated. Values at the center of the stroke were also taken in the case of dynamic runs.

d. Calculation of the Coefficient of Friction

The coefficient of friction is determined by dividing the friction force by the normal force. The normal force is the basic load, 32.1 pounds, plus 11 times the weight applied to the weight tray.

The friction force is calculated from the maximum deflection on the recorder for one cycle of movement (Fig. 2). In the case of the dynamic trials, the deflection value representing the force due to acceleration must be subtracted before friction calculations. This correction is unnecessary for the mid-stroke deflection since, theoretically, the acceleration is zero at this point.

The deflection must be divided by 2 since a compressive and a tensile force are applied in the reciprocating motion of the block. Also, the deflection must be halved again since two separate friction forces are developed in opposing the motion of the movable block. One of the friction forces results from the contact of the upper stationary block with the upper surface of the movable block. A similar condition exists at the lower surface of the moving block and the lower stationary block (Fig. 1).

The two friction forces are assumed to be equal. These forces differ slightly in that, at the lower surface, the load has increased by the weight of the middle block. Since the middle movable block weighs only 1/4 pound, this factor is neglected.

PROCEDURE - Continued

The friction force in pounds thus can be determined by dividing the total deflection by 4 and multiplying by the calibration factor of 5 pounds per millimeter.

When high friction forces were present it was necessary to change the attenuator on the amplifier from the 1 scale to the 4 scale. This, in essence, cut the deflection fourfold and increased the calibration factor to 20 pounds per millimeter.

4. RESULTS AND DISCUSSION

a. Reproducibility of Results

A reproducibility study was conducted with the use of zinc and manganese phosphate coatings in both the dry and the lubricated condition. A total of 5 static trials with each trial having 16 different loads were run for the dry coatings. The lubricated coatings had 4 static trials with each trial containing 36 different loads. Since load had no apparent effect on the coefficient of friction, as shown later, mean values were calculated.

Standard deviations for the results on each different coating were also calculated and are found in Tables I through IV. The largest deviation was noted in the results for tests on dry manganese phosphate coatings. The deviation from the mean was ±.049 when the mean coefficient of friction was found to be .913. The 95 per cent confidence level for the mean of large samples equals 1.96 times the standard deviation. Thus, the confidence limits of 95 per cent for the coefficient of friction of dry manganese phosphate coatings are approximately .81 and 1.01. This indicates adequate reproducibility of the results if the possible errors in the experimental method are concerned. The probable cause for much of the experimental error is in the reading of the recorder deflection.

A friction study by the Jet Propulsion Laboratory at the California Institute of Technology showed a similar degree of reproducibility.[2] Coefficients of friction near 1.00, found by the Jet Propulsion Laboratory, had an estimated standard deviation of ±.05 and friction coefficients near 0.20 had an approximate deviation of ±.035.

RESULTS AND DISCUSSION - Continued

The dynamic testing did not yield reproducible results for the dry coatings. The high friction forces resulted in galling, and erratic results were obtained.

Results were obtainable for the lubricated phosphate coatings under dynamic conditions. The results, however, were not as consistent as those for the static tests. For example, the mean value of the dynamic coefficient of friction for lubricated manganese phosphate was .153 ± .046. The static coefficient of friction for the same coating was .147 ± .011.

b. Comparison of Zinc versus Manganese Phosphate

A large amount of data was compiled on zinc and manganese phosphate coatings to determine whether a difference exists between the two coatings in frictional characteristics. The mean static coefficient of friction for dry manganese and dry zinc phosphate were .911 and .876, respectively. Lubricated manganese phosphate gave a mean coefficient of .147, whereas the lubricated zinc phosphate gave .145. The complete data can be found in Tables I through IV.

It is difficult to determine whether there is a significant difference between the zinc and manganese phosphate on the basis of mean values alone. The "t" test can be used to determine whether the mean of one set of values is significantly different statistically from the mean of another set.[3]

With the "t" test as a basis for comparison, the mean values for dry zinc phosphate coatings were significantly different from dry manganese phosphate coatings. The "t" test indicated that dry zinc phosphate coatings had slightly improved frictional properties over dry manganese phosphate. The value of t calculated for the dry coatings exceeded the table value at the 99 per cent level. Thus, there is over a 99 per cent degree of assurance that the mean of the zinc phosphate differs from the mean of the manganese phosphate.

A similar "t" test was made on the lubricated coatings. No significant difference between the zinc and manganese phosphate coatings in the lubricated state was found. The mean values of the dynamic coefficients also substantiated the fact that there is no difference between zinc and manganese phosphate when lubricated.

RESULTS AND DISCUSSION - Continued

During the static friction testing, the dry manganese phosphate coatings powdered more than the dry zinc phosphate coatings. This resulted in some bare spots in the coating at the conclusion of the test. This possibly was due to the fact that the zinc phosphate was a thicker coating.

Most of both coatings were worn off at the conclusion of the dynamic testing. The coefficient of friction did not appear to be dependent upon the amount of coating worn off just as long as the coating retained a sufficient amount of oil to maintain good lubrication.

Lubricated manganese phosphate coatings, during dynamic testing, were broken in almost immediately. The zinc phosphate coatings generally required 30 seconds to a minute to completely break in the coating and give a constant coefficient of friction.

c. Effect of Load

The load was varied during the static testing from 32.1 pounds to 417.1 pounds. This represents pressures from approximately 50 pounds per square inch to 670 pounds per square inch. In some trials, the load appeared to have a slight effect on the coefficient. In these instances, however, an increase in load sometimes resulted in an increase and sometimes, a decrease in the coefficient. This phenomenon was probably due to the fact that the rollers, used to align the friction blocks, had a tendency to support a small part of the load. It was concluded that the load did not significantly affect the coefficient of friction. Tichvinsky has shown that the coefficient is independent of load for hard steel on hard steel and nickel on mild steel over a similar range of load.[4]

During the dynamic tests, the load was varied from 32.1 to 307.1 pounds. The coefficient of friction did not appear to be dependent upon the load except for one load of 197.1 pounds. At this particular load, the coefficient was always higher. It is believed that this increased value was due to slight tilting of the upper friction block which caused uneven wear. Further investigation is necessary to determine the exact nature of the high friction forces at 197.1 pounds. The friction values at this load were discounted in the determining of the mean dynamic coefficients of friction since the probable cause of the discrepancy was of a mechanical nature.

RESULTS AND DISCUSSION - Continued

d. Effect of Lubrication

It is evident that phosphate coatings with MIL-L-644 oil have vastly improved frictional characteristics over dry coatings. Lubrication reduced the static coefficient sixfold from its value in the dry state. Goodman has stated in his Laws of Friction for Lubricated Surfaces that the coefficient of friction of well-lubricated surfaces is from 1/16 to 1/10 that of dry or poorly lubricated surfaces.[5] This indicates that phosphate coatings are not natural lubricants. The advantage is that these coatings act as excellent retainers for lubricants and offer fast break-in qualities.

e. Effect of Surface Roughness

Three different surface preparations were used prior to phosphating. Vapor-blasting with an SiO_2 abrasive (No. 200) produced a surface roughness of 14 to 16 microinches (r.m.s.). After phosphating, the roughness was raised to 30 to 32 microinches (r.m.s.). Grit-blasting with steel grit (No. 120) gave profilometer readings of 55 to 65 microinches, whereas grit blasting with a mixture of numbers 50 and 80 gave readings of 60 to 70 microinches. The surface roughness readings after phosphating for the different grit-blasted surfaces, however, were the same (50-60 microinches r.m.s.).

The static coefficient of friction did not vary between the grit blasted samples. These data can be found in Table V. The smoother phosphate surface produced by vapor-blasting did slightly lower the coefficient for dry coatings. The mean coefficient was .858 as compared with .897 and .899 for the grit-blasted surfaces. This difference was proved to be statistically significant with the use of the "t" test.

The results for smooth phosphate coatings in the lubricated state can be found in Table VI. Comparison of the results in this table with those of Table III shows that the coefficient has increased for the smoother surface. This possibly indicates that a smoother phosphate coating is not completely effective as a retainer for lubricants.

RESULTS AND DISCUSSION - Continued

f. Effect of Crystalline Structure

Coarse crystalline manganese phosphate coatings were obtained by using a 50 per cent hydrochloric acid dip before phosphating instead of blasting. The static coefficients for these coatings can be found in Table VII. Comparison of the coarse crystalline coatings with the values of the standard coatings in Tables I and III showed that the dry crystalline coatings exhibited better frictional characteristics than the standard coatings. The dry coarse crystalline coating is harder and more brittle than a normal phosphate coating, thus peaks are easily fractured and less resistance to sliding is present.

In the lubricated state, however, the coarse coatings had a higher mean coefficient than the standard manganese phosphate coatings. These data appear to contradict the results discussed in the previous section since the smoother coatings also had a higher mean coefficient. This leads one to believe that an optimum crystal size or roughness exists for the lubricated phosphate coating naving the best frictional characteristics.

g. Comparison of Static and Dynamic Coefficients

Tables of friction coefficients found in standard compilations generally show that the static coefficients are approximately 40 per cent greater than the dynamic coefficients.[6] A comparison of the static and dynamic coefficients found in Tables III, IV, VIII and IX shows that the mean dynamic coefficients approximate the mean static coefficients. The mean static coefficients for zinc and manganese phosphate are .145 and .147, respectively, whereas the mean maximum dynamic coefficients for zinc and manganese phosphate are .150 and .153, respectively.

Rabinowicz states that for some sliding combinations there is no difference between the static and the dynamic coefficients.[7] Some movement of a stationary system will occur, even on application of a value of the friction force smaller than that corresponding to the dynamic coefficient. In essence, the breakaway coefficient equals the dynamic coefficient for the initial sliding speed. Lubricated phosphate coatings appear to be surfaces that behave in this manner.

RESULTS AND DISCUSSION - Continued

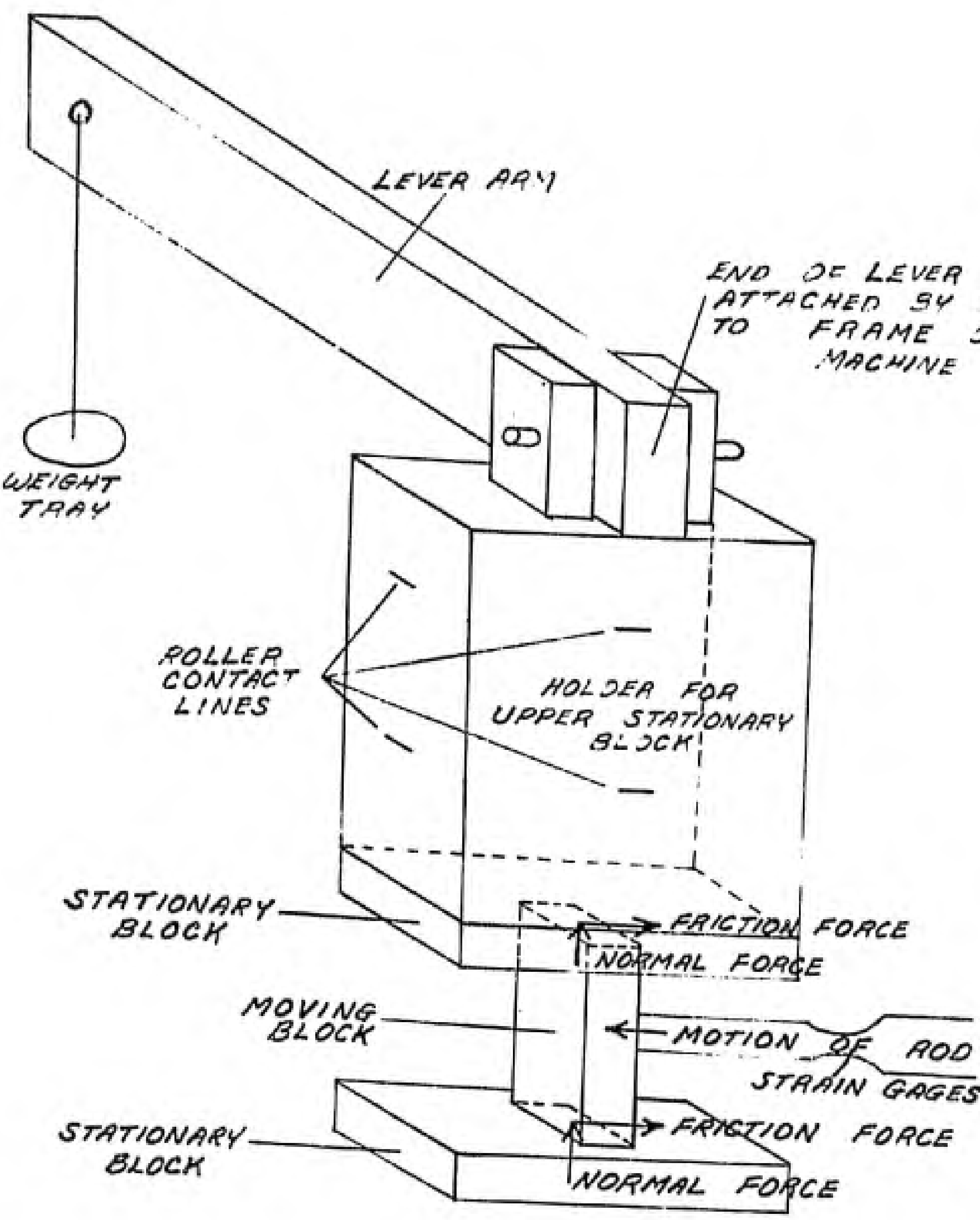
During the dynamic testing, the recording paper speed was increased. This increased speed made it possible to record the change in friction force with velocity for the reciprocating movement. It was noticed that the friction force at low loads appeared to reach a minimum value at the center of a stroke, the point at which velocity is a maximum (Fig. 3). At high loads, the recordings showed the friction force to be a maximum at one end of the stroke and a minimum at the other end. The maximum friction force for the load with apparent uneven wear occurred at the middle of the stroke. Further investigation is necessary to determine whether these differences are due to mechanical alignment of the friction blocks or actually frictional phenomenon.

Coefficients of friction were determined from the mid stroke deflections. The mean coefficient for zinc phosphate was .113 and for manganese phosphate .116. These values indicate that the dynamic coefficient is dependent upon velocity.

APPENDIX A - Figures

REPORT
SA-TR18-1084

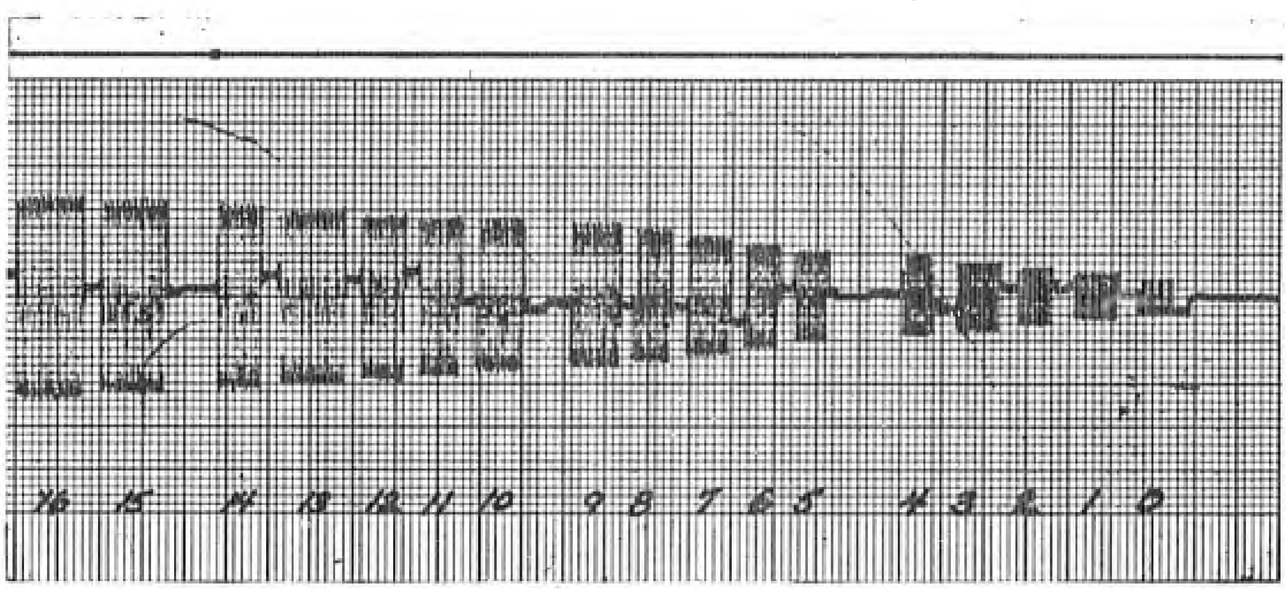
FIGURE 1 SCHEMATIC DIAGRAM OF THE LOADING OF WEIGHTS



NOTE 1) THE ROLLERS ARE ATTACHED TO THE FRAME WHICH ENCLOSES THE HOLDER FOR THE UPPER STATIONARY BLOCK.

2) THE EFFECT OF THE FRICTION FORCES ON THE GAGES IS COMPRESSIVE. WHEN MOTION REVERSES, THE EFFECT OF THE FORCES IS TENSILE.

FIGURE 2 TYPICAL RECORDER DEFLECTIONS FOR A STATIC TRIAL USING LUBRICATED MANGANESE PHOSPHATE BLOCKS. LOAD ON LEVER ARM INCREASED FROM 0 TO 35 LBS. IN ONE LB. INCREMENTS.



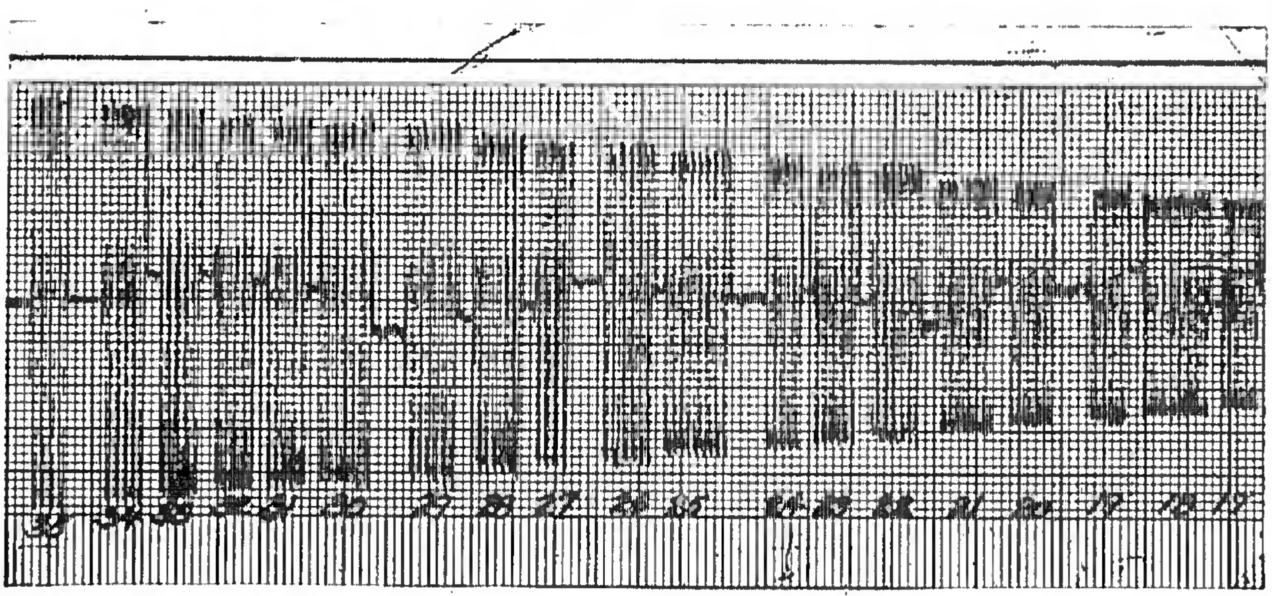
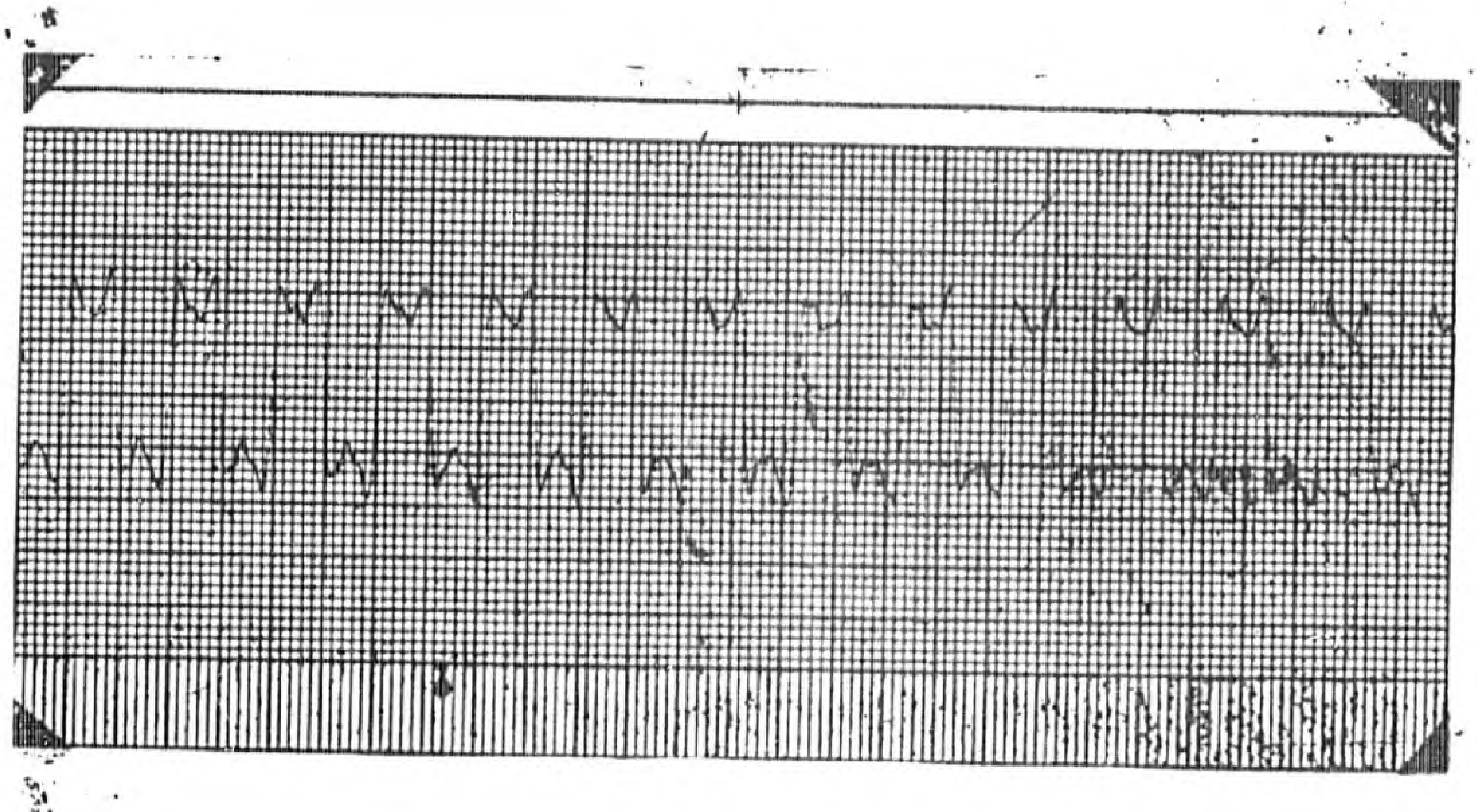
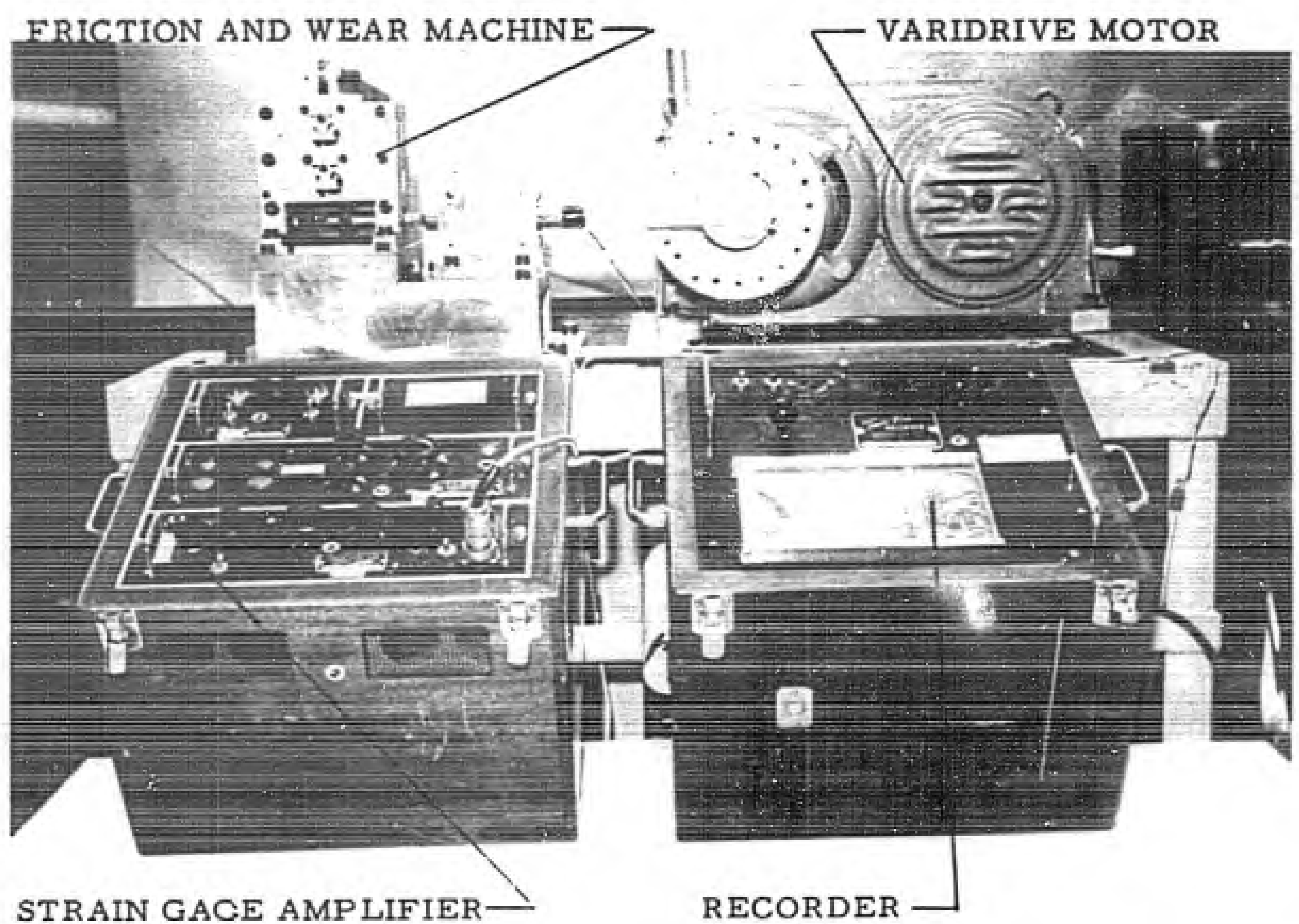
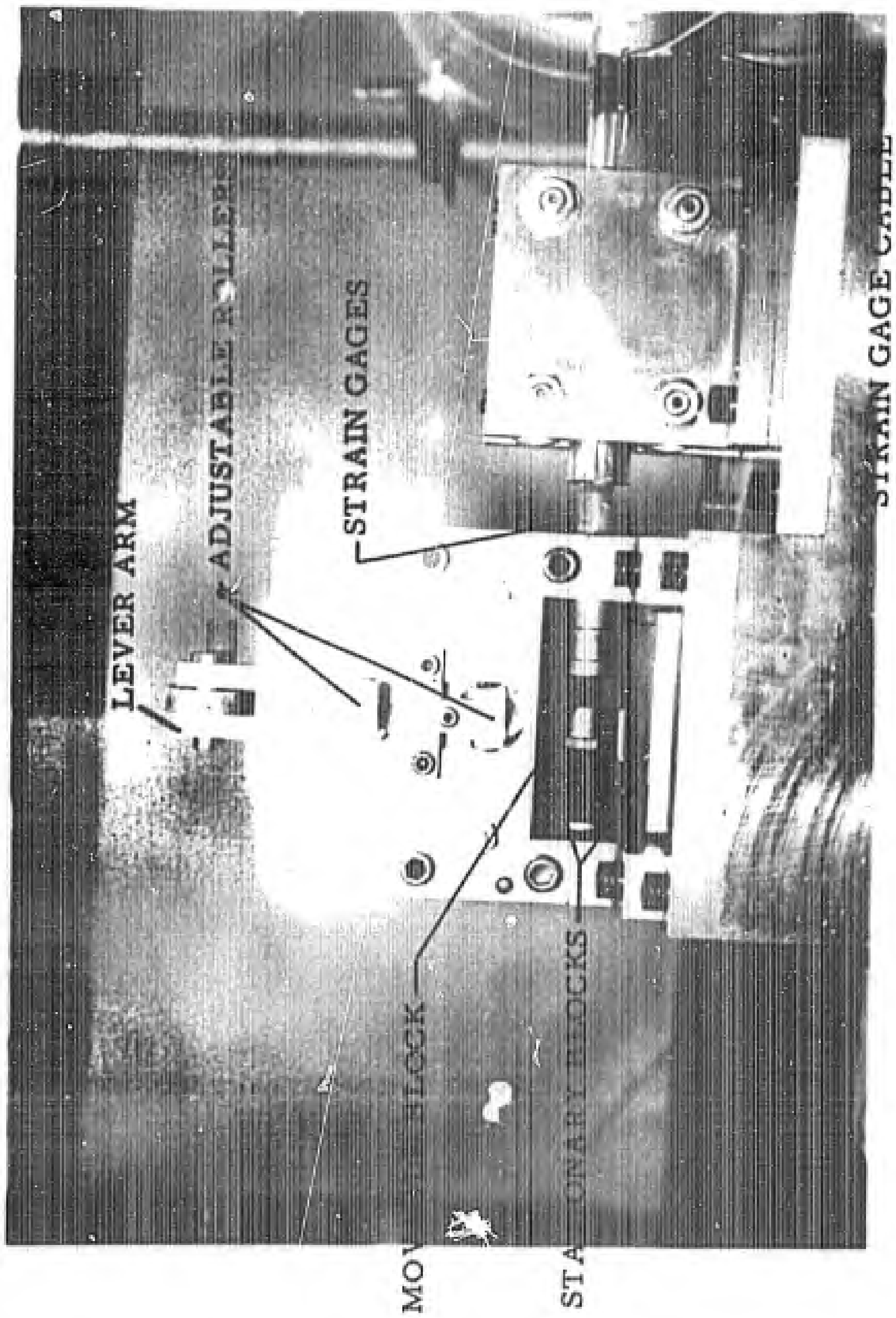


FIGURE 3 TYPICAL RECORDER DEFLECTION FOR A DYNAMIC TRIAL USING LUBRICATED ZINC PHOSPHATE BLOCKS. LOAD ON LEVER ARM IS 10 LBS.





19-058-546/AMC-63 U. S. ARMY - SPRINGFIELD ARMORY 22 July 1963
SPRINGFIELD ARMORY FRICTION AND WEAR MACHINE WITH SUPPLEMENTARY INSTRUMENTATION

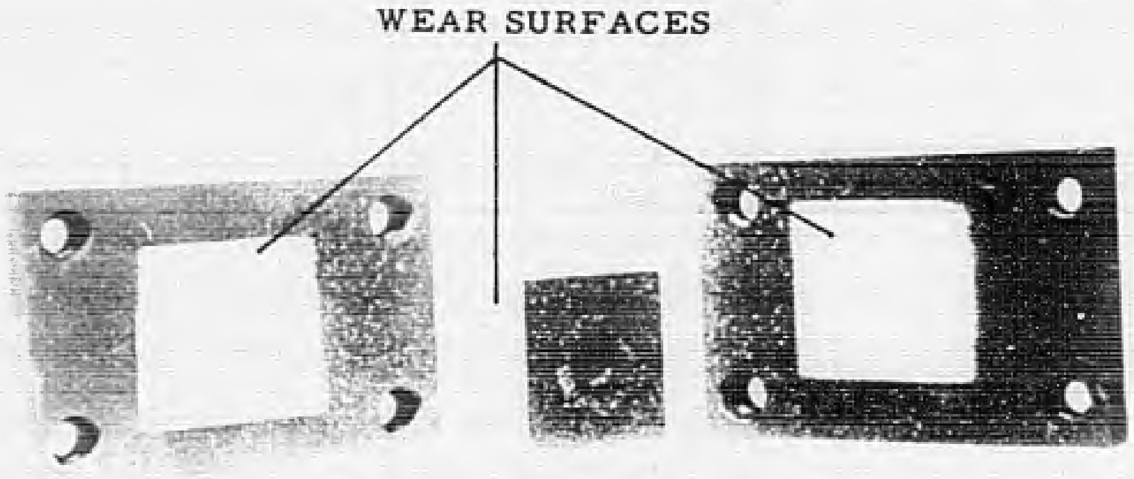


U. S. ARMY - SPRINGFIELD ARMORY

SPRINGFIELD ARMORY FRICTION AND WEAR MACHINE

19-058-548/AMC-63

22 July 1963



19-058-547/AMC-63 U. S. ARMY - SPRINGFIELD ARMORY 22 July 1963

PHOSPHATED SPECIMENS AFTER TEST IN SPRINGFIELD ARMORY FRICTION AND WEAR MACHINE WITH SUPPLEMENTARY INSTRUMENTATION

APPENDIX B - Tables

TABLE 7

STATIC COEFFICIENT OF FRICTION FOR DRY MANGANESE PHOSPHATE COATINGS

LOAD APPLIED TO LEVER ARM	ACTUAL NORMAL FORCE	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TRIAL 5	
		RECORDER DEFLECTION	COEFFICIENT OF FRICTION	RECORDER DEFLECTION	COEFFICIENT OF FRICTION	RECORDER DEFLECTION	COEFFICIENT OF FRICTION	RECORDER DEFLECTION	COEFFICIENT OF FRICTION	RECORDER DEFLECTION	COEFFICIENT OF FRICTION
POUNDS	POUNDS	MILLIMETERS	FRICTION	MILLIMETERS	FRICTION	MILLIMETERS	FRICTION	MILLIMETERS	FRICTION	MILLIMETERS	FRICTION
0	32.1	21 ①	.82	23	.90	19	.74	25	.97	28	.86
1	43.1	30	.87	31	.90	30	.87	33	.96	31	.90
2	54.1	39	.90	43	.99	40	.92	40	.92	36	.93
3	65.	47	.90	13 ②	1.00	12 ②	.92	12 ②	.92	11 ②	.84
4	76.1	14 ②	.92	15	.99	14	.92	14	.92	10.5	.82
5	87.1	15.5	.94	17	.96	15.5	.89	16	.92	14.5	.83
6	98.1	17.5	.89	19	.97	19	.97	18.5	.94	17	.86
7	109.1	19.5	.89	21	.96	21	.96	20	.92	19	.87
8	120.1	21.5	.89	23	[illegible]	23	.96	22	.92	21	.87
9	131.1	24	.91	25	.95	25	.95	24	.92	23	.88
10	142.1	26	.92	27	.95	27	.95	26	.92	25	.88
11	153.1	28	.91	29	.95	29	.95	28	.92	27	.83
12	164.1	30	.91	30.5	.93	31	.94	30.5	.93	29	.88
13	175.1	31	.89	32.5	.93	33	.94	33	.94	30	.86
14	186.1	34	.91	34.5	.93	35	.94	34	.91	32	.86
15	197.1	36	.91	36	.91	37	.94	36	.91	34	.86

MEAN COEFFICIENT FOR ALL TRIALS EQUALS .913
STANDARD DEVIATION FROM THE MEAN EQUALS ±.049

NOTES: ① EXPRESSED IN MILLIMETERS AND INCLUDES TOTAL OF TENSION AND COMPRESSION DEFLECTION FOR ONE CYCLE OF MOVEMENT.
② AMPLIFIER ATTENUATOR CHANGED FROM 1 TO 4 SCALE.

REPORT
SA-TR18-1084

TABLE II

STATIC COEFFICIENT OF FRICTION FOR DRY ZINC PHOSPHATE COATINGS

LOAD APPLIED TO LEVER ARM	ACTUAL NORMAL FORCE	TRIAL 1 RECORDER DEFLECTION	TRIAL 1 COEFFICIENT	TRIAL 2 RECORDER DEFLECTION	TRIAL 2 COEFFICIENT	TRIAL 3 RECORDER DEFLECTION	TRIAL 3 COEFFICIENT	TRIAL 4 RECORDER DEFLECTION	TRIAL 4 COEFFICIENT	TRIAL 5 RECORDER DEFLECTION	TRIAL 5 COEFFICIENT
0	32.1	22	.86	22	.86	22	.86	24	.93	20.5	.80
1	43.1	31	.90	31	.90	30	.87	29.5	.94	28.5	.87
2	54.1	38	.88	39	.90	36	83	40	.93	36	.83
3	65.1	11.5 (1)	.88	11 (1)	.84	10.5 (1)	.81	12 (1)	.92	11 (1)	.84
4	76.1	13	.85	13	.85	13	.85	14	.92	12.5	82
5	87.1	15	.86	15	86	15	.86	16	.92	14.5	.83
6	98.1	17	.87	17	.87	16.5	.84	17.5	.89	17	.85
7	109.1	19	.87	19	.87	19	.87	19.5	.89	19	87
8	120.1	21	.88	21	.87	21	.87	21.5	.89	21	.87
9	131.1	24	.92	23	.88	22.5	.86	23.5	.90	23	.88
10	142.1	26	.92	25	.88	25	.88	25.5	.90	25	.88
11	153.1	28	.91	26.5	86	27	.88	27.5	.90	27	.88
12	164.1	30	.91	29	.88	28.5	87	29.5	.90	28.5	.87
13	175.1	31	.89	30	.86	30	86	32	.91	31	.88
14	186.1	33	.89	33	89	31.5	.85	33.5	.90	33	.89
15	197.1	35	.89	35	.89	32.5	.85	36	.91	35	.89

MEAN COEFFICIENT FOR ALL TRIALS EQUALS .876
STANDARD DEVIATION FROM THE MEAN EQUALS ±.028

NOTES: (1) AMPLIFIER ATTENUATOR CHANGED FROM 1 TO 4 SCALE.

TABLE III

STATIC COEFFICIENT OF FRICTION FOR OILED MANGANESE PHOSPHATE COATINGS

LOAD APPLIED TO LEVER ARM	ACTUAL NORMAL FORCE	TRIAL 1 RECORDER DEFLECTION	TRIAL 1 COEFFICIENT	TRIAL 2 RECORDER DEFLECTION	TRIAL 2 COEFFICIENT	TRIAL 3 RECORDER DEFLECTION	TRIAL 3 COEFFICIENT	TRIAL 4 RECORDER DEFLECTION	TRIAL 4 COEFFICIENT
0	32.1	3.5	.14	4.5	.18	4	.16	3.5	.14
1	[illegible]	4.75	.14	6.5	.19	6	.17	5	.15
2	54.1	6	.14	7.75	.18	7.25	.17	6.5	.15
3	65.1	7.5	.14	9.5	.18	8.5	.16	7.5	.14
4	76.1	8.5	.14	11	.18	10	.16	9	.15
5	87.1	9.75	.14	12.5	.18	11	.16	10.5	.15
6	98.1	11.25	.14	13	.17	12.25	.16	12	.15
7	109.1	12.75	.15	14	.16	14	.16	13.5	.16
8	120.1	14.5	.15	15.5	.16	15	.16	15.5	.16
9	131.1	16	.16	16.5	.16	16.25	.16	17	.16
10	142.1	17	.15	17.5	.15	17.5	.15	18	.16
11	153.1	17.5	.14	18.5	.15	18.5	.15	18	.15
12	164.1	18.5	.14	20	.15	20	.15	19.5	.15
13	175.1	19	.14	21	.15	22	.16	20.5	.15
14	186.1	20	.13	22	.15	23	.15	22	.15
15	197.1	21.5	.14	23	.15	24	.15	24	.15
16	208.1	22.5	.14	24	.14	25	.15	25	.15
17	219.1	23.5	.13	25	.14	26	.15	26.5	.15
18	230.1	25	.14	26	.14	27	.15	28	.15
19	241.1	26	.14	28	.15	28.5	.15	29.5	.15
20	252.1	27.5	.14	28.5	.14	31	.15	30	.15
21	263.1	28.5	.14	29	.14	31	.15	31.5	.15
22	274.1	30	.15	30	.14	32	.15	33	.15
23	285.1	31.5	.14	31	.14	34	.15	33.5	.15
24	296.1	33	.14	32	.14	35	.15	34	.14
25	307.1	34.5	.14	33	.13	36	.15	36	.15
26	318.1	36	.14	34	.13	36.5	.14	37	.15
27	329.1	37	.14	35	.13	37.5	.14	38	.14
28	340.1	38	.14	36	.13	38	.14	39	.14
29	351.1	41	.15	37	.13	39	.14	41	.15
30	362.1	41	.14	38	.13	40	.14	42	.15
31	373.1	42	.14	39.5	.13	41	.14	42.5	.14
32	381.1	43	.14	42	.14	42	.14	44	.14
33	395.1	44.5	.14	42.5	.13	43	.14	44	.14
34	406.1	45.5	.14	43	.13	44	.14	45.5	.14
35	417.1	47	.14	45	.14	45	.14	46	.14

MEAN COEFFICIENT FOR ALL TRIALS EQUALS .147
STANDARD DEVIATION FROM THE MEAN EQUALS ±.011

REPORT
SA-TR18-1084

TABLE IV

Static Coefficient of Friction for Oiled Zinc Phosphate Coatings

Load Hanger on Lever Arm	Actual Normal Force	Trial 1 Recorder Deflection	Trial 1 Coefficient	Trial 2 Recorder Deflection	Trial 2 Coefficient	Trial 3 Recorder Deflection	Trial 3 Coefficient	Trial 4 Recorder Deflection	Trial 4 Coefficient
0	32.1	3	.12	3	.12	3.5	.14	3.25	.13
1	43.1	4.25	.12	4.25	.12	4.75	.14	4.75	.14
2	54.1	5.75	.13	5.5	13	6	.14	6	.14
3	65.1	7	.13	6.75	.13	7.5	.14	7	.13
4	76.1	7.5	.13	8	.13	8.5	.14	8.25	.14
5	87.1	10	.14	9.25	.13	10	.14	9.5	.14
6	98.1	11.5	.15	10.5	.13	11	.14	11	.14
7	109.1	13	.15	11.75	.14	12.5	.14	12.25	.14
8	120.1	15	.16	12.75	.13	13.5	.14	13.75	.14
9	131.1	16.5	.16	14	.13	14.5	.14	15	.14
10	142.1	18.5	.16	15	.13	15.75	.14	16.5	.15
11	153.1	20	.16	16.25	.13	17	.14	18	.15
12	164.1	22	.17	17.5	.13	18	.14	19	.15
13	175.1	24	.17	18.75	.13	19.5	.14	21	.15
14	186.1	26	.17	20	.13	20.5	.14	22	.15
15	197.1	28	.18	21	.13	22	.14	23.5	.15
16	208.1	29.5	.18	22	.13	23	.14	25	.15
17	219.1	31	.18	23	.13	24	.14	26	.15
18	230.1	32	.17	24	.13	25.5	.14	28	.15
19	241.1	33	.17	25.5	.13	27	.14	29	.15
20	252.1	34	.17	27	.13	28	.14	30	.15
21	263.1	35.5	.17	28	.13	29.5	.14	31	.15
22	274.1	37	.17	29.5	.13	30.5	.14	32	.15
23	285.1	38.5	.17	30.75	.14	32	.14	34	.15
24	296.1	40	.17	34	.14	33	.14	35	.15
25	307.1	41.5	.17	34	.14	34	.14	36	.15
26	318.1	10.5 (1)	.17	34.5	.14	35.5	.14	37	.15
27	329.1	11.25	.17	35.5	.14	37	.14	38.5	.15
28	340.1	11.50	.17	36.5	.13	38	.14	40.5	.15
29	351.1	11.75	.17	37	.13	39	.14	41	.15
30	362.1	12	.17	39	.14	40	.14	42	.15
31	373.1	12.5	.17	42	.14	41.5	.14	43.5	.15
32	384.1	13	.17	43	.14	42.5	.14	44.5	.15
33	395.1	13.5	.17	44.5	.14	43.5	.14	46	.15
34	406.1	14	.17	46	.14	44.5	.14	47	.15
35	417.1	14.5	.17	47	.14	46	.14	48.5	.15

Mean Coefficient for All Trials Equals .145
Standard Deviation from the Mean Equals ±.014

Notes (1) Amplifier Attenuator Changed From 1 To 4 Scale

TABLE V

EFFECT OF SURFACE ROUGHNESS ON STATIC COEFFICIENT OF FRICTION

		Grit Blast - Mixture of No. 50 and 80 Steel Grit. Roughness Readings (1): Before Phosphating 60-70, After Phosphating 50-60				Vapor Blast - Abrasive No. 200. Roughness Readings: Before Phosphating 14-16, After Phosphating 30-35				Grit Blast - No 120 Steel Grit. Roughness Readings: Before Phosphating 55-65, After Phosphating 50-65			
		Trial 1		Trial 2		Trial 1		Trial 2		Trial 1		Trial 2	
Load Applied to Lever Arm	Actual Normal Force	Recorder Deflection	Coefficient	Recorder Deflection	Coefficient	Recorder Deflection	Coefficient	Recorder Deflection	Coefficient	Recorder Deflection	Coefficient	Recorder Deflection	Coefficient
0	32.1	23	.90	22	.86	22	.86	21	.82	25	.97	23	.90
1	43.1	32	.93	31	.87	30	.87	28	.81	33	.96	28	.82
2	54.1	40	.92	39	.90	36	.83	36	.83	41	.95	37	.86
3	65.1	11 (2)	.85	12 (2)	.92	44	.84	11 (2)	.84	12 (2)	.92	12 (2)	.92
4	76.1	13	.85	14	.92	12 (2)	.79	13	.86	14	.92	14	.92
5	87.1	14.5	.83	16	.92	15	.86	15	.86	15.5	.89	16	.92
6	98.1	16	.82	18	.92	17	.86	17	.86	17	.86	18	.92
7	109.1	18	.83	20	.92	19	.87	19	.57	19	.87	20	.92
8	120.1	20	.83	23	.96	21	.87	21	.87	21	.57	22	.92
9	131.1	22.5	.86	24	.92	22.5	.86	23	.88	23	.88	24	.92
10	142.1	25	.88	26	.92	24	.85	25	.88	25	.58	26	.92
11	153.1	28	.91	29	.95	26	.85	27	.88	27	.86	28	.91
12	164.1	31	.94	30	.91	28	.85	29	.88	29	.86	29	.89
13	175.1	32	.92	33	.94	31	.88	31	.88	31	.86	30	.86
14	186.1	33	.89	34	.91	32	.86	33	.84	33	.89	32	.86
15	197.1	36	.91	36	.91	34	.86	35	.84	35	.89	35	.89
		Mean Value .897				Mean Value .858				Mean Value .899			

NOTES:
1. RMS VALUES ON A PROFILOMETER
2. AMPLIFIER ATTENUATOR CHANGED FROM 1 TO 4 SCALE
3. ALL SPECIMENS WERE DRY MANGANESE PHOSPHATE

REPORT
SA-TR18-1084

TABLE VI

EFFECT OF SURFACE ROUGHNESS ON STATIC CO-EFFICIENT OF FRICTION

LOAD APPLIED TO LEVER ARM	ACTUAL NORMAL FORCE	TRIAL 1 RECORDER DEFLECTION	TRIAL 1 COEFFICIENT	TRIAL 2 RECORDER DEFLECTION	TRIAL 2 COEFFICIENT
0	32.1	4	.16	5.5	.21
1	43.1	6	.17	7.5	.22
2	54.1	7	.16	9	.21
3	65.1	9	.17	11	.21
4	76.1	11	.18	12.5	.21
5	87.1	13.5	.19	14.5	.21
6	98.1	16	.20	17	.21
7	109.1	17.5	.20	18.5	.21
8	120.1	19	.20	20.5	.21
9	131.1	21	.20	22.5	.21
10	142.1	23.5	.21	24	.21
11	153.1	25.5	.21	26	.21
12	164.1	27	.20	28	.21
13	175.1	29	.21	30	.21
14	186.1	31	.21	32	.22
15	197.1	33	.21	33	.21
16	208.1	35	.21	36	.22
17	219.1	37	.21	38	.22
18	230.1	39	.21	39	.21
19	241.1	40	.21	42	.22
20	252.1	42	.21	43	.21
			MEAN VALUE		.209

NOTES (1) MANGANESE PHOSPHATE SPECIMENS WITH OIL. VAPOR BLAST (ABRASIVE NO. 200) PREPARATION

REPORT
SA-TR18-1084

TABLE VII
STATIC COEFFICIENT OF FRICTION FOR COURSE CRYSTALLINE PHOSPHATE COATINGS

		DRY MANGANESE PHOSPHATE COATINGS				OILED MANGANESE PHOSPHATE COATINGS			
		TRIAL 1		TRIAL 2		TRIAL 1		TRIAL 2	
LOAD APPLIED TO LEVER ARM	ACTUAL NORMAL FORCE	RECORDER DEFLECTION	COEFFICIENT	RECORDER DEFLECTION	COEFFICIENT	RECORDER DEFLECTION	COEFFICIENT	RECORDER DEFLECTION	COEFFICIENT
0	32.1	21	.82	20	.78	4.5	.18	5	.19
1	43.1	28	.81	25	.73	6.5	.19	7	.20
2	54.1	35	.81	31	.72	8	.18	8.5	.19
3	65.1	42	.81	37	.71	9.5	.18	10	.19
4	76.1	12 (1)	.79	10 (1)	.66	11	.18	12	.19
5	87.1	13	.75	12	.69	12	.17	13	.19
6	98.1	15	.76	14	.71	12.5	.17	14.5	.18
7	109.1	17	.78	16	.73	15	.17	16.5	.19
8	120.1	19	.79	18	.75	16	.17	18	.19
9	131.1	21	.80	20	.76	17.5	.17	19	.18
10	142.1	22	.78	22	.78	19	.17	20.5	.18
11	153.1	24	.78	23	.75	20	.16	22	.18
12	164.1	26	.79	25	.76	21.5	.16	24	.18
13	175.1	28	.80	27	.77	23	.16	26	.19
14	186.1	30	.81	28	.75	24.5	.16	27.5	.19
15	197.1	32	.81	30	.76	25.5	.16	29	.18
16	208.1					27	.16	31	.19
17	219.1					29	.16	33	.19
18	230.1					30	.16	35	.19
19	241.1					31	.16	37	.19
20	252.1					32	.16	38	.19

MEAN VALUE .766 MEAN VALUE .178

NOTES: (1) AMPLIFIER ATTENUATOR CHANGED FROM 1 TO 4 SCALE.

REPORT
SA-TR18-1084

TABLE VIII

DYNAMIC COEFFICIENTS OF FRICTION FOR LUBRICATED MANGANESE PHOSPHATE COATINGS

TRIAL 1

Load Applied To Lever Arm In LBS	Actual Normal Force In LBS	Recorder Deflection At Mid-Stroke mm.	Coefficient	Max. Recorder Deflection (mm)	Coefficient
0	32.1	3	.12	5	.15
5	87.1	8	.11	12	.16
10	142.1	11	.10	18	.15
15	197.1	30	.18	30	.19
20	252.1	24	.12	28	.13
25	307.1	29	.12	35	.14

TRIAL 2

Load Applied To Lever Arm In LBS.	Actual Normal Force In LBS.	Recorder Deflection At Mid-Stroke(mm)	Coefficient	Max Recorder Deflection (mm)	Coefficient
0	32.1	4	.15	6	.19
5	87.1	8	.11	13	.17
10	142.1	12	.11	20	.17
15	197.1	34	.21	34	.21
20	252.1	25	.12	29	.14
25	307.1	28	.11	33	.13

TRIAL 3

Load Applied To Lever Arm LBS.	Actual Normal Force In LBS	Recorder Deflection At Mid-Stroke mm	Coefficient	Max. Recorder Deflection (mm)	Coefficient
0	32.1	3	12	5	16
5	87.1	8	.11	13	.17
10	142.1	11	.10	20	.17
15	197.1	32	.20	32	.20
20	252.1	25	.12	31	.15
25	309.1	31	.13	36	.15

TRIAL 4

Load Applied To Lever Arm In LBS	Actual Normal Force In LBS	Recorder Deflection At Mid Stroke (mm)	Coefficient	Max. Recorder Deflection (mm)	Coefficient
0	32.1	3	.12	5	16
5	87.1	8	11	11	.14
10	142.1	11	.10	20	.17
15	197.1	33	.20	33	.20
20	252.1	26	.13	32	.15
25	307.1	29	.12	34	.13

TRIAL 5

Load Applied To Lever Arm In LBS	Actual Normal Force In LBS	Recorder Deflection At Mid-Stroke(mm)	Coefficient	Max. Recorder Deflection (mm)	Coefficient
0	32.1	3	.12	5	.16
5	87.1	7	.10	11	.14
10	142.1	11	.10	18	.15
15	197.1	33	.21	33	.21
20	252.1	26	.13	31	.15
25	307.1	30	.12	37	.15

MEAN COEFFICIENTS — MID STROKE .116; MAXIMUM .153

VALUES AT 15 LBS. ARE NOT INCLUDED IN MEAN
STANDARD DEVIATION FROM THE MEAN FOR MAXIMUM DEFLECTIONS EQUALS ±.046

REPORT
SA-TR18-1084

TABLE IX
DYNAMIC COEFFICIENTS OF FRICTION FOR LUBRICATED ZINC PHOSPHATE COATINGS

TRIAL 1

LOAD APPLIED TO LEVER ARM IN LBS	ACTUAL NORMAL FORCE IN LBS	RECORDER DEFLECTION AT MID STROKE (mm)	COEFFICIENT	MAX. RECORDER DEFLECTION (mm)	COEFFICIENT
0	32.1	3	.12	5	.16
5	87.1	7	.10	11	.14
10	142.1	10	.09	19	.16
15	197.1	32	.20	32	.20
20	252.1	26	.13	30	.14
25	307.1	30	.12	35	.14

TRIAL 2

LOAD APPLIED TO LEVER ARM IN LBS	ACTUAL NORMAL FORCE IN LBS	RECORDER DEFLECTION AT MID STROKE	COEFFICIENT	MAX. RECORDER DEFLECTION (mm)	COEFFICIENT
0	32.1	3	.12	5	.16
5	87.1	7	.10	13	.17
10	142.1	10	.09	19	.16
15	197.1	34	.21	34	.21
20	252.1	25	.12	29	.14
25	307.1	30	.12	35	.14

TRIAL 3

LOAD APPLIED TO LEVER ARM IN LBS.	ACTUAL NORMAL FORCE IN LBS.	RECORDER DEFLECTION AT MID STROKE (mm)	COEFFICIENT	MAX. RECORDER DEFLECTION (mm)	COEFFICIENT
0	32.1	3	.12	5	.16
5	87.1	8	.11	10	.13
10	142.1	10	.09	19	.16
15	197.1	35	.21	35	.21
20	252.1	24	.12	30	.14
25	307.1	29	.12	35	14

TRIAL 4

LOAD APPLIED TO LEVER ARM IN LBS	ACTUAL NORMAL FORCE IN LBS	RECORDER DEFLECTION AT MID STROKE (mm)	COEFFICIENT	MAX. RECORDER DEFLECTION (mm)	COEFFICIENT
0	32.1	3	.12	5	.16
5	87.1	8	.11	11	.14
10	142.1	11	.10	19	.16
15	197.1	33	.20	33	.20
20	252.1	23	.11	29	.14
25	307.1	29	.12	35	.14

TRIAL 5

LOAD APPLIED TO LEVER ARM IN LBS.	ACTUAL NORMAL FORCE IN LBS	RECORDER DEFLECTION AT MID STROKE (mm)	COEFFICIENT	MAX. RECORDER DEFLECTION (mm)	COEFFICIENT
0	32.1	3	.12	5	.16
5	87.1	8	.11	11	.14
10	142.1	12	.11	20	.17
15	197.1	35	.21	35	.21
20	252.1	25	.13	31	.15
25	307.1	29	.12	34	.14

MEAN COEFFICIENTS MID STROKE .113
MAXIMUM .150

VALUES AT 15 LBS ARE NOT INCLUDED IN MEAN
STANDARD DEVIATION FROM THE MEAN FOR MAXIMUM DEFLECTIONS EQUALS ±.010.

APPENDIX C - Bibliography

BIBLIOGRAPHY

1. Rabinowicz, E. "Practical Approach to Friction Coefficients." Product Engineering (26 Sep 1960), p62.

2. Rittenhouse, J. B.; Jaffe, L. B.; Nagler, R. G.; and Martens, H. E. Friction Measurements on a Low Earth Satellite. Jet Propulsion Laboratory, California Institute of Technology. Technical Report No. 32-402, 1963, p 12.

3. Brownlee, K. Industrial Experimentation. (Brooklyn, New York: Chemical Publishing Co., Inc. 1949) p 34.

4. Tichvinsky, L. M. Steel. 104 46 (June 5, 1939).

5. Esbach, O. W., Ed. Handbook of Engineering Fundamentals. (New York: John Wiley and Sons, Inc., 1936) pp 4-44.

6. Rabinowicz, E., p 64.

7. Rabinowicz, E., p 64.

APPENDIX D - Distribution

DISTRIBUTION

	Copies
Commanding General U.S. Army Materiel Command Bldg. T-7, Rm 817 Department of the Army Washington, D. C. 20315	1
Commanding General ATTN: Technical Library Aberdeen Proving Ground, Maryland 21005	1
Commanding Officer U.S. Army Coating and Chemical Laboratory Aberdeen Proving Ground, Maryland 21005	2
Commanding General U.S. Army Weapons Command ATTN: AMSWE-RD (1) AMSWE-RDF3 (1) Rock Island, Illinois 61202	2
Commanding General U.S. Army Ballistic Missile Agency ATTN: Documents and Technical Information Branch (2) Redstone Arsenal, Alabama	2
Commanding Officer Frankford Arsenal ATTN: SMUFA-1330 (1) Library-0270 (1) Philadelphia 37, Pennsylvania	2
Commanding Officer Army Materials Research Agency Watertown Arsenal ATTN: SMIWT-RPB Watertown 72, Massachusetts	1
Commanding Officer Picatinny Arsenal Dover, New Jersey 07801	1

DISTRIBUTION

	Copies
Commanding General U.S. Army Weapons Command ATTN: AMSWE-RD Rock Island, Illinois 61202	3
Commanding Officer Office of the Quartermaster General ATTN: Research and Development Division Washington 25, D.C.	1
President, U.S. Army Armor Board U.S. Continental Army Command Fort Knox, Kentucky 40121	1
Commander Air Proving Ground Center ATTN: PGTRI, Technical Library Eglin Air Force Base, Florida	1
Commander Air Research and Development Command Andrews Air Force Base ATTN: RDT-DAG Washington 25, D.C.	1
Chairman, National Aeronautics & Space Administration Lewis Research Center 21000 Brookpark Road Cleveland 25, Ohio	1
Chief, Bureau of Aeronautics Department of the Navy Airborne Equipment Division ATTN: Materials Branch, Code AE-44 Washington 25, D.C.	1
Commander, U.S. Naval Air Experimental Station Building 600 Philadelphia 12, Pennsylvania	1

DISTRIBUTION

	Copies
Commanding Officer Rock Island Arsenal ATTN: SWERI - Materials Section, Laboratory Rock Island, Illinois 61202	2
Commanding Officer Watertown Arsenal ATTN: SMIWT-LX Watertown 72, Massachusetts	1
Commanding Officer Watervliet Arsenal ATTN: SWEWV-RD Watervliet, New York 12189	1
Commanding Officer Harry Diamond Laboratories ATTN: AMXDO-TIB Connecticut Avenue and Van Ness Street, N.W. Washington, D.C. 20438	1
Commanding Officer Engineer Research and Development Laboratory ATTN: STEPR-Materials Branch Ft. Belvoir, Virginia	1
Headquarters U.S. Army Signal Research and Development Lab. ATTN: Materials Branch Fort Monmouth, New Jersey	1
Commander U.S. Army Research Office Arlington Hall Station Arlington 12, Virginia	1
Commanding Officer U.S. Army Research Office Box CM Duke Station Durham, North Carolina	1

DISTRIBUTION

	Copies
Commanding General U.S. Army Test and Evaluation Command ATTN: Technical Library, Bldg 313 (2) Director, Infantry Materiel Testing (2) Aberdeen Proving Ground, Maryland 21005	4
Chief, Bureau of Naval Weapons Department of the Navy ATTN: RMMP Room 2225, Munitions Building Washington 25, D.C.	1
Office of Naval Research Department of the Navy ATTN: Code 423 Washington 25, D.C.	1
Commander U.S. Naval Research Laboratory ATTN: Technical Information Center Anacostia Station Washington 25, D.C.	1
Wright Air Development Division ATTN: ASRCEE-1 (1) WWRCO (1) Materials Control (1) Wright-Patterson Air Force Base, Ohio	3
Commanding Officer Defense Documentation Center Cameron Station Alexandria, Virginia 22314	10
Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena, California	1

AD ____________ Accession ____________

Springfield Armory, Springfield, Mass.
FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael A. George, Technical Report SA-TR18-1084, 9 April 1964, 38 pages including tables and illustrations. CMS Code 5016.11.84400.02. PRON. M1-3-50015-02-M1-M6.

UNCLASSIFIED REPORT.

NONLIMITED DISTRIBUTION.

A friction and wear machine has been developed at Springfield Armory to simulate the frictional characteristics of reciprocating weapon components. The machine was used to evaluate the various factors influencing the friction of phosphate coatings. Coefficients of friction for the coatings were determined under static and dynamic conditions. The following factors influencing the coefficient of friction are considered: type of coating, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not differ to any practical extent from the coefficients for zinc phosphate coatings. Lubrication is a significant factor on the coefficients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing, surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed.

1. Friction and Wear
2. Phosphate Coatings
3. Lubrication
4. Small Arms

AD ____________ Accession ____________

Springfield Armory, Springfield, Mass.
FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael A. George, Technical Report SA-TR18-1084, 9 April 1964, 38 pages including tables and illustrations. CMS Code 5016.11.84400.02. PRON. M1-3-50015-02-M1-M5.

UNCLASSIFIED REPORT.

NONLIMITED DISTRIBUTION.

A friction and wear machine has been developed at Springfield Armory to simulate the frictional characteristics of reciprocating weapon components. The machine was used to evaluate the various factors influencing the friction of phosphate coatings. Coefficients of friction for the coatings were determined under static and dynamic conditions. The following factors influencing the coefficient of friction are considered: type of coating, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not differ to any practical extent from the coefficients for zinc phosphate coatings. Lubrication is a significant factor on the coefficients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing, surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed.

1. Friction and Wear
2. Phosphate Coatings
3. Lubrication
4. Small Arms

AD ____________ Accession ____________

Springfield Armory, Springfield, Mass.
FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael A. George, Technical Report SA-TR18-1084, 9 April 1964, 38 pages including tables and illustrations. CMS Code 5016.11.84400.02. PRON. M1-3-50015-02-M1-M6.

UNCLASSIFIED REPORT.

NONLIMITED DISTRIBUTION.

A friction and wear machine has been developed at Springfield Armory to simulate the frictional characteristics of reciprocating weapon components. The machine was used to evaluate the various factors influencing the friction of phosphate coatings. Coefficients of friction for the coatings were determined under static and dynamic conditions. The following factors influencing the coefficient of friction are considered: type of coating, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not differ to any practical extent from the coefficients for zinc phosphate coatings. Lubrication is a significant factor on the coefficients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing, surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed.

1. Friction and Wear
2. Phosphate Coatings
3. Lubrication
4. Small Arms

AD ____________ Accession ____________

Springfield Armory, Springfield, Mass.
FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael A. George, Technical Report SA-TR18-1084, 9 April 1964, 38 pages including tables and illustrations. CMS Code 5016.11.84400.02. PRON. M1-3-50015-02-M1-M6.

UNCLASSIFIED REPORT.

NONLIMITED DISTRIBUTION.

A friction and wear machine has been developed at Springfield Armory to simulate the frictional characteristics of reciprocating weapon components. The machine was used to evaluate the various factors influencing the friction of phosphate coatings. Coefficients of friction for the coatings were determined under static and dynamic conditions. The following factors influencing the coefficient of friction are considered: type of coating, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not differ to any practical extent from the coefficients for zinc phosphate coatings. Lubrication is a significant factor on the coefficients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing, surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed.

1. Friction and Wear
2. Phosphate Coatings
3. Lubrication
4. Small Arms